HIRDLS

SP-HIR-069C

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: J. G. Whitney Date: 97-10-20

Subject/Title: **HIRDLS INSTRUMENT SPECTRAL REQUIREMENTS**

Description/Summary/Contents:

SCOPE

This document specifies the required spectral character-
istics for the HIRDLS instrument.

The performance figures herein apply to "beginning of
life (BOL)", i.e. as delivered and as incorporated into
the "BOL" columns of the SPRAT OPDETPRE Budget table.

This document forms part of a sequence which defines the
flow-down of HIRDLS spectral requirements from the Instrument
Requirements Document to the various coating specification
documents. The sequence is explained in document PM-OXF-153A.

Keywords: Filter; Coating; Lens; Mirror; Window; Spectral; Passband; Blocking

Purpose of this Document:

Reviewed/Approved by: Date (yy-mm-dd):			

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1. INTRODUCTION

1.0 Change Log

(changes since rev. B dated 16th July 1996)

> In several places: "telescope", "transmitting component train" and "transmitting optical train" changed to "optical system".
> Contents table: updated [everything from section 3.3 to end deleted from this document and moved to SP-HIR-155]
> Section 1.0: CHANGE LOG updated.
> Para. 1.1.2: "optical system" defined to include mirrors.
> Para. 1.2.2: a) changed to include mirrors
d) wording corrected; "<10%" figure added.

> Table 1a: title changed.
> Section 1.3: a) wording changed to include mirrors.
> Section 1.4: reference to SC-HIR-018 deleted;
reference to SP-HIR-155 added;
> Section 1.5: new section; refers to spectral flow-down diagram.
> Para. 2.1.6: wording updated.
> Para. 2.1.8: new para. added to specify mirror reflectance
> Table 2a: headings in cols. 5 & 6 changed to "LW/SW 50% point" ("upper/lower" considered ambiguous)
> Table 2b: new col. 4 inserted to show minimum mirror reflectance; col. 5 (was col. 4) numbers reduced to allow for mirrors.
> Para. 2.2: reference to SP-HIR-155 added to reflect the fact that the component-level test requirements have been transferred from this document (SP-HIR-069) to SP-HIR-155.
> Paras 3.1.1, 3.1.2: materials specs. clarified, based on data received from Howard Morrow
> Section 2.3: last para. re-worded to update the descriptions of, and references to, documents SP-HIR-155 and TC-RDU-111.
> Para 3.2.2: "at the 2%" changed to "between the 1% and 5%"
> Para 3.2.3: specific thermal background noise requirement added
> Para 3.2.4: deleted (redundant, given the changes listed above and the amalgamation of the PASSBAND and BLOCKING Budget descriptions into a single document: TC-RDU-111)
> Section 3.3: moved to SP-HIR-155
> Section 5: moved to SP-HIR-155
> Section 6: moved to SP-HIR-155

1.1 Definitions and abbreviations

1.1.1 The terms 'passband' and 'bandwidth' refer to the full spectral width between the 50% (of maximum) relative transmission points

1.1.2 In the context of this document the term "optical system" means the ensemble of mirrors, lenses, detector dewar window, "warm" bandpass filters and "cold" bandpass filters.

1.1.3 BOL = beginning of life; HPP = half power point

1.2 HIRDLS optical components

1.2.1 The HIRDLS optical system is required to meet all specified performance requirements over the whole spectral frequency range from 555 to 1650 cm-1 (wavelength range 6 to 18.5 microns), except where otherwise stated.

1.2.2 The optical system includes the following components, which are also listed in Table 1:

a) several mirrors;

b) a pair of Germanium lenses, whose primary function is to form an image of the 21-channel (System Field Stop) detector element array, with appropriate magnification, at the far focus of the main Ellipsoid Mirror. Lens L1 also serves to form an image of the System Aperture Stop in the plane of the Intermediate Lyot Stop;

c) a Zinc Selenide plane window, whose primary function is to form a transparent vacuum seal at the entrance to the Detector Dewar Assembly, and whose secondary function is to provide additional spectral blocking at the long wave end of the HIRDLS spectral band;

d) a pair of multilayer, bandpass filters on Germanium substrates in each of the 21 spectral channels, the functions of which are to define the channel passband, to provide adequate attenuation of unwanted energy due to multiple reflections (ghosting) and to out-of band spectral leakage and - in the case of the Cold Filters which are of various substrate thicknesses - to compensate for 'chromatic' aberrations between channels and to reduce the level of "warm background" flux noise incident on each detector element to <10% of the detector noise.

e) an anti-reflection coated photo-conductive array of 21 MCT detector elements.

NOTE: The substrate materials specified herein have been assumed in the optical imaging design of the telescope, and may not be changed without formal agreement

Table 1a - COMPONENTS OF HIRDLS OPTICAL SYSTEM

(listed approximately in sequence from entrance aperture to detectors)

component	form	desig.	nom centre thicknss	approx beam f/no.	surface or bulk material	approx. operating temperature
scan mirror	plane	FM0	---	--	Au	20 C
primary mirror	parab	M1	---	--	Au	20 C
secondary mirror	ellip	M2	---	--	Au	20 C
warm filter	plane	WF	0.90	7.96	Ge	20 C
lens L1	meniscus	L1	3.50	--	Ge	20 C
folding mirror	plane	FM4	---	23.27	Au	20 C
lens L2	meniscus	L2	3.00	--	Ge	20 C
window	plane	W1	2.00	1.44	ZnSe	15 C
cold filter	plane	CF	0.45	1.44	Ge	65 K
detector	-	-	---	--	HgCdTe	65 K

Table 1b - OTHER HIRDLS OPTICAL COMPONENTS

chopper mirror	plane	FM3	---	2.72	Au	20 C
space view mir.	toroid	M5	---	--	Au	20 C
IFC mirror	parab	M6	---	--	Au	20 C

1.3 Summary of channel spectral requirements

The HIRDLS instrument is an infrared radiometer with 21 channels viewing the limb of the earth's atmosphere in various spectral intervals in the range 6 to 18 microns, plus an optics alignment channel having the same nominal spectral profile as channel 20.

The spectral profile of each channel will in principle depend on the spectral characteristics of every component in the optical system. The components fall into four categories:

a) mirrors: these are all in the common optical train for all channels; they will probably be coated with electrolytic gold; the minimum required reflectance at BOL is given in this document; the combined spectral response of the various mirrors in the optical system shall be taken into account and may affect the design of the components in categories b) and/or c).

b) window and lenses: these components are also in the common optical train for all channels; their spectral performance requirements are addressed in this specification document; these components require anti-reflection coatings effective over the whole spectral range given in para 1.1; the combined spectral response of these components may be "tailored" to contribute some out-of-band attenuation, and will in any case interact with the design of some of the components in category c).

c) bandpass filters: the spectral performance requirements for these components are addressed in this specification document; each channel requires a conjugate pair of bandpass filters in series in the optical train - one "warm" (20 C) and one "cold" (65 K) - to attenuate out-of-field "ghost" responses and out-of-band spectral "leaks" to a sufficient degree, and to limit warm-backgound flux noise in the detector elements to an acceptable level.

d) detectors: in each channel the detector element is immediately behind the Cold Filter. Each detector will be anti-reflection coated and there may - in the spectrally widest channels - be a non-negligible 'slope' in the spectral response across the passband. With regard to the out-of-band regions, the detector element response will gradually decrease at shorter wavelengths and will decrease more rapidly towards longer wavelengths.

1.4 Reference Documents [for each item the latest revision is implied]

SP-HIR-13	Instrument Technical Specification
SP-OXF-48	Requirements for documentation of measured filter passbands
SP-HIR-154	Out-of-band Spectral Blocking Requirements
TC-HIR-57	System Performance Requirements & Allocation Tables (SPRAT)
TC-RDU-5	Feasibility study for HIRDLS filters - final report
TC-RDU-107	Average integrated filter transmissions
SP-HIR-155	Spectral Performance Requirements for HIRDLS Optical Elements
TC-RDU-111	Spectral PASSBAND and BLOCKING Budget Description Document
TC-RAL-042	Angle of Incidence Distributions
TC-RAL-047	Ghost analysis plan
TC-RAL-047/1	Ghost analysis results

Document precedence

In the event of any conflict between this document (SP-HIR-69) and any of the above-listed reference documents, the order of precedence is:

1. SP-HIR-13
2. this document
3. other listed -HIR- documents
4. other listed documents

1.5 Spectral requirements flow-down diagram

Attention is drawn to the notes and diagram in PM-OXF-153A ("HIRDLS Instrument Spectral Requirements Flowdown"). This shows how the spectral requirements have been documented, from the IRD down to the individual coating specification documents. In particular, PM-OXF-153A illustrates the places occupied by the present document (SP-HIR-069) and SP-HIR-155.

2. SPECTRAL REQUIREMENTS FOR COMPLETE CHANNELS

2.1 Performance requirements

2.1.1 The spectral bandpass profile for each channel shall conform to the values and tolerances given for the half power (i.e. 50% of peak transmission) points in Table 2a (cols. 5 & 6). For reference only, the desired (ideal) half power points (HPP) are shown in col. 4.

2.1.2 For each channel at least one of the following three requirements relating to passband shape shall be met:

a) the integrated transmission between the 0.2% and the 50% relative transmission points (upper and lower added) shall contribute no more than 30% of the integrated transmission between the 50% relative transmission points, and/or:

b) the 5% relative transmission points shall both lie within the limits given in Table 2b (col. 3), and/or:

c) the width of the spectral interval between the 5% relative transmission points shall not exceed 1.6 times the desired passband width as given in Table 2a (col. 4)

2.1.3 The overall absolute transmission of the optical system, averaged over the central 10% of the passband, shall be as high as possible, and shall be equal to or greater than the figure given in Table 2b (col. 5)

2.1.4 On the upper and lower edges of the passband respectively, the transmission of each channel shall fall monotonically from the 50% relative transmission point to the 0.2% relative transmission point

2.1.5 The relative spectral response of each channel shall be such that, when viewing a 300 K black body, the total radiance ("leakage" signal):

a) integrated over the spectral interval between 250 and 6500 cm-1, but outside the passband of each channel, shall not exceed 0.25% of the in-band radiance in that channel, and

b) averaged over any 10-wavenumber spectral interval between 250 and 6500 cm-1, but outside the passband of each channel, shall not exceed 1E-7 of the peak in-band transmission, except between 400 and 500 cm-1 where it shall not exceed 1E-6 of the peak in-band transmission

For these requirements only, the passband shall be assumed to extend on each side of the nominal passband of each channel to the closest of the points:

a) at which the relative transmission has fallen monotonically to 1E-7, or

b) at which the relative transmission has fallen monotonically to a local minimum value greater than 1E-7, or

c) which is three times the bandwidth away from the band centre

2.1.6 The out-of-band spectral blocking coatings for each component in the optical system shall be designed so that the overall blocking levels specified above will be achieved after integration of the whole telescope optical system. The analytical, synthetical and other relevant data used to show how individual component blocking profiles have been derived from these requirements shall be described in "TC-RDU-111: "Spectral PASSBAND and BLOCKING Budget Description Document", and included in the compilation of the SP-HIR-155 spectral design spreadsheet.

2.1.7 In considering the spectral blocking and throughput aspects of the coated optics performance, the thicknesses of the component substrates shall be taken as given in Table 1, and the materials as specified in paras 3.1.1, 3.1.2 and 3.2.1

2.1.8 The absolute reflectance of each mirror surface in the optical system at BOL shall be equal to or greater than the value shown in Table 2b, (col. 4).

Table 2a - SPECTRAL PASSBANDS

1	2	3	4	5	6
Channel #	Gas	Centre (approx) (micron)	Desired Passband (cm-1)	Required LW 50% pt. (cm-1)	Required SW 50% pt. (cm-1)
1	N2O/Aero	17.4	563 - 588	563.5(+/-)2.0	587.25(+/-)1.0
2	CO2 (L)	16.5	600 - 615	600.5(+/-)2.0	614.75(+/-)1.0
3	CO2 (M)	16.0	610 - 640	610.0(+/-)3.0	639.5(+/-)2.0
4	CO2 (M)	15.6	626 - 660	626.0(+/-)3.0	660.0(+/-)3.0
5	CO2 (H)	15.0	655 - 680	655.0(+/-)3.0	680.0(+/-)3.0
6	Aero	12.1	821 - 836	821.5(+/-)2.3	835.0(+/-)2.4
7	CFC-11	11.8	835 - 853	835.0(+/-)2.4	852.0(+/-)2.4
8	HNO3	11.3	860 - 905	861.5(+/-)2.5	903.5(+/-)2.5
9	CFC-12	10.8	915 - 933	916.0(+/-)2.6	931.5(+/-)2.6
10	O3 (L)	10.1	990 - 1010	991.0(+/-)2.8	1009.0(+/-)2.8
11	O3 (H)	9.57	1011 - 1048	1011.0(+/-)2.9	1046.5(+/-)2.9
12	O3 (L)	8.85	1120 - 1140	1120.0(+/-)3.2	1138.5(+/-)3.2
13	Aero	8.26	1200 - 1220	1202.0(+/-)3.4	1220.0(+/-)3.4
14	N2O5	8.04	1229 - 1260	1229.5(+/-)2.0	1259.75(+/-)1.0
15	N2O	7.88	1256 - 1282	1256.25(+/-)1.0	1281.75(+/-)1.0
16	ClONO2	7.76	1278 - 1299	1278.25(+/-)1.0	1298.75(+/-)1.0
17	CH4	7.43	1324 - 1369	1325.5(+/-)3.8	1367.5(+/-)3.8
18	H2O (L)	7.09	1385 - 1435	1387.0(+/-)4.0	1435.0(+/-)4.0
19	Aero	7.10	1402 - 1416	1402.25(+/-)1.0	1415.75(+/-)1.0
20	H2O (H)	6.75	1422 - 1542	1422.0(+/-)4.1	1542.0(+/-)4.3
21	NO2	6.22	1582 - 1634	1585.5(+/-)4.5	1630.5(+/-)4.6
22	(test)	6.75	1422 - 1542	(nominal)	

Table 2b - SPECTRAL RESPONSE & TRANSMISSION

1	2	3	4	5
Channel #	Gas	5% rel response limits (cm-1)	Minimum mirror reflectance	Minimum overall transmission
1	N2O/Aero	556 - 595	98.8 %	7 %
2	CO2 (L)	596 - 619	98.8 %	17 %
3	CO2 (M)	601 - 649	98.7 %	24 %
4	CO2 (M)	616 - 670	98.7 %	28 %
5	CO2 (H)	648 - 687	98.7 %	37 %
6	Aero	817 - 840	98.6 %	41 %
7	CFC-11	830 - 858	98.6 %	43 %
8	HNO3	847 - 918	98.6 %	55 %
9	CFC-12	910 - 938	98.6 %	51 %
10	O3 (L)	984 - 1016	98.5 %	52 %
11	O3 (H)	1000 - 1059	98.5 %	58 %
12	O3 (L)	1114 - 1146	98.5 %	52 %
13	Aero	1194 - 1226	98.5 %	52 %
14	N2O5	1220 - 1269	98.5 %	55 %
15	N2O	1249 - 1289	98.5 %	53 %
16	ClONO2	1272 - 1305	98.5 %	50 %
17	CH4	1311 - 1382	98.5 %	56 %
18	H2O (L)	1370 - 1450	98.5 %	54 %
19	Aero	1398 - 1420	98.5 %	37 %
20	H2O (H)	1386 - 1578	98.5 %	58 %
21	NO2	1567 - 1649	98.5 %	51 %
22	(test)		98.5 %	50 %

2.2 Formal verification of instrument spectral characteristics

It is intended to verify by test at instrument-level prior to calibration that the end-to-end spectral passband for each channel, i.e. the nominal half-power points and the shape factor, are within the stated limits.

Subsequent instrument-level calibration will include tests to verify that the requirements of paras 2.1.2 and 2.1.4 herein have been met.

It is not expected that the requirements of paras 2.1.3 and 2.1.5 can be verified at instrument level. These will be verified by synthesis of the results of the component-level tests defined in SP-HIR-155.

2.3 Flow-down of spectral requirements to components

The design of the overall spectral characteristics of the optical system involves close interaction between components within several instrument subsystems. The flow-down of the instrument spectral requirements is primarily controlled by this document, taking into account not only the overall spectral response requirements given in the ITS (SP-HIR-13) but also the spectral response and surface reflectance constraints or assumptions derived from the out-of-field ("ghosting") analysis reported in TC-RAL-047 and -047/1, as well as the optical throughput figures used in the OPDETPRE Budget (TC-HIR-57, Section 4.9).

For each channel, the bandpass and out-of-band blocking designs for the warm and cold filters may to some extent be traded between these components to make the best use of the respective temperature-dependent spectral characteristics of each conjugate pair. In a few channels the spectral characteristics of the lenses and window unavoidably influence both the in-band and out-of-band overall spectral response, and these must be included in the design process and flow-down.

For the above reasons a coherent set of component spectral performance profiles for the HIRDLS instrument has been developed. These profiles will be developed and documented in the spectral design spreadsheet and accompanying document SP-HIR-155: "Spectral performance requirements for HIRDLS optical elements". The process by which these profiles have been developed, with related assumptions and caveats, will be found in TC-RDU-111: "Spectral PASSBAND and BLOCKING Budget Description Document"

3. COMPONENT SPECTRAL REQUIREMENTS DERIVED FROM OPTICAL SYSTEM DESIGN

3.1 Lenses and window

3.1.1 Lenses L1 and L2 shall be manufactured from "optical grade" germanium. The material shall be monocrystalline, N-type, with its axis nominally parallel to the lens optical axis, and shall have a resistivity of <25 ohm-cm. Index of refraction inhomogeneity shall be such that each lens shall produce less than .02 waves RMS at 3.4 microns.

3.1.2 The bulk material used to manufacture Window W1 shall be optical grade Zinc Selenide with an index of refraction inhomogeneity not exceeding 5 ppm.

3.1.3 Lens L1 shall conform to the performance requirements given in Table 3.1 (cols. 4a and 5a) over each of the specified channel passbands between the 5% relative response points, but not necessarily in the intervening spectral intervals

3.1.4 Lens L2 shall conform to the performance requirements given in Table 3.1 (cols. 4b and 5b) over each of the specified channel passbands between the 5% relative response points, but not necessarily in the intervening spectral intervals

3.1.5 Window W1 shall conform to the performance requirements given in Table 3.1 (cols. 6 and 7) over each of the specified channel passbands between the 5% relative response points, but not necessarily in the intervening spectral intervals

3.1.6 The surface reflectance of the anti-reflection coating on each lens and window surface at approximately normal incidence shall not exceed 2.8% over each of the specified channel passbands between the 5% relative response points (Table 3.1, col. 3), but not necessarily in the intervening spectral intervals [Note: this is the intended maximum beginning-of-life figure. The corresponding maximum end-of-life figure is 3% per surface]

Table 3.1 - LENSES & WINDOW

1	2	3	4a	4b	5a	5b	6	7
Ch. #	Gas	Centre (approx) (micron)	Minimum substrate transmission at centre L1	L2	Maximum absorption in A/R coatings (2 surfaces) L1	L2	Minimum substrate transmissn W1	Maximum absorption in A/R coatings (2 surfaces) W1
1	N2O	17.4	0.555	0.598	3 %	3 %	0.843	3 %
2	CO2	16.5	0.818	0.835	3 %	3 %	0.861	3 %
3	CO2	16.0	0.781	0.802	3 %	3 %	0.872	3 %
4	CO2	15.6	0.746	0.771	3 %	3 %	0.891	3 %
5	CO2	15.0	0.807	0.825	3 %	3 %	0.920	3 %
6	Aero	12.1	0.880	0.889	3 %	3 %	0.942	3 %
7	CFC-11	11.8	0.879	0.888	3 %	3 %	0.942	3 %
8	HNO3	11.3	0.928	0.930	3 %	3 %	0.942	3 %
9	CFC-12	10.8	0.932	0.934	3 %	3 %	0.942	3 %
10	O3	10.1	0.936	0.937	3 %	3 %	0.942	3 %
11	O3	9.57	0.936	0.937	3 %	3 %	0.942	3 %
12	O3	8.85	0.937	0.937	3 %	3 %	0.942	3 %
13	Aero	8.26	0.937	0.937	3 %	3 %	0.942	3 %
14	N2O5	8.04	0.936	0.937	3 %	3 %	0.942	3 %
15	N2O	7.88	0.936	0.937	3 %	3 %	0.942	3 %
16	ClONO2	7.76	0.936	0.937	3 %	3 %	0.942	3 %
17	CH4	7.43	0.936	0.937	3 %	3 %	0.942	3 %
18	H2O	7.09	0.936	0.937	3 %	3 %	0.942	3 %
19	Aero	7.10	0.936	0.937	3 %	3 %	0.942	3 %
20	H2O	6.75	0.936	0.937	3 %	3 %	0.942	3 %
21	NO2	6.22	0.937	0.937	3 %	3 %	0.942	3 %
22	(test)	6.75	(nominally as Channel 20)					

Note: the overall spectral range covered by Table 3.1 is 555 to 1650 cm-1

/3.2 Bandpass Filters . . . . .

3.2 Bandpass Filters

3.2.1 The bulk material used to manufacture the bandpass filters shall be Germanium, optical grade 5-20 Ohm.cm, monocrystalline, with the 111 axis parallel to the principal axis of the blank.

3.2.2 In each channel the overall passband shall be primarily defined by the warm filter. The cold filter passband shall be chosen such that the 50% relative transmission points are pitched approximately between the 1% and 5% relative transmission points of the conjugate warm filter.

3.2.3 In each channel the overall transmission profile of each Detector/Cold-Filter combination shall be such that the total RMS noise due to the incident thermal flux outside the 5% relative transmission points for the Detector/Cold-Filter combination does not exceed 10% of the RMS noise due to the incident thermal flux within the 5% relative transmission points for the Detector/Cold-Filter combination.

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